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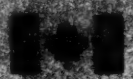

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VIDEO DISPLAY TERMINALS — DO THEY EMIT DANGEROUS LEVELS OF RADIATION?

NRCC No. 27845

NATIONAL RESEARCH COUNCIL OF CANADA
NRCC ASSOCIATE COMMITTEE ON SCIENTIFIC CRITERIA FOR
ENVIRONMENTAL QUALITY

VIDEO DISPLAY TERMINALS -

DO THEY EMIT DANGEROUS LEVELS OF RADIATION?

by

A.M. Muc

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All documents published by the Associate Committee are published in both French and English.

ACKNOWLEDGEMENTS

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NOTE TO READERS

Readers of this document will note that it does not follow the usual format of criteria documents issued by the Associate Committee on Scientific Criteria for Environmental Quality in that references to the scientific literature are not contained in the body of the document. Such references have not been included because the Associate Committee intends that the document simply convey to readers an assessment, by recognized, experienced, professional scientists, of all the criteria issues connected with the use of VDTs, without encumbering the manuscript with the technical references essential to a criteria document.

The "Further Reading" list at the end of the document directs any interested reader to criteria documents and a few other key articles in which all the appropriate technical references can be found. The publications and articles listed should give anyone interested a clear and suitably referenced picture of the rationale applied in reaching the conclusions stated in this document. Furthermore, much of the content of this document is at such a very basic scientific and technical level that citation of references is felt to be quite inappropriate.

TABLE OF CONTENTS

		PAGE
1.0	Introduction	1
2.0	Radiation	1
3.0	How VDTs Work	2
4.0	X Radiation	4
5.0	Ultraviolet (UV) Radiation	6
6.0	Visible Radiation	7
7.0	Infrared (IR) Radiation	7
8.0	Microwave Radiation	8
9.0	Radiofrequency (RF) Radiation	9
10.0	Low Frequency (LF) Radiation	9
11.0	Static Fields	10
12.0	Ultrasound	11
13.0	Old or Defective VDTs	11
14.0	A Final Word on Radiation	12
15.0	A Brief Note on Statistical "Clusters"	12
FURTHER READING		16

1.0 INTRODUCTION

Video display terminals (VDTs), also known as visual display units (VDUs), cathode ray tubes (CRTs) or monitors, are becoming more and more common. Although they have already seen wide use in television receivers, they are now appearing by the thousands as an integral part of business computers, word processors, video games and personal computers. They are used in government offices, throughout business and industry, in schools and in private homes. Numerous questions have been raised about their potential effects on the health of operators.

Many agencies and task forces have studied the questions raised by the widespread introduction and use of VDTs in particular, and microelectronic technology in general. They have identified a number of "problems" related to the physical layout of the equipment and the environment in which it is installed (ergonomic and human factors aspects), and the processes by which the new technology is introduced and how it changes jobs and prospects for advancement or employment (social, political and psychological aspects). Not the least of these "problems" has been the widespread fear of radiation and associated suggestions that a variety of health problems such as headaches, skin rashes, cataracts and other damage to the visual system, miscarriages and birth defects are caused by radiation emissions from VDTs (scientific, technical and medical aspects). The assessment of radiation effects is within the terms of reference of the former Physical Energy Phenomena (PEP) Subcommittee of the National Research Council of Canada's Associate Committee on Scientific Criteria for Environmental Quality. Consequently, and also because of distortions and misinformation presented in the news media and by some special interest groups, the PEP Subcommittee prepared this document to provide the Canadian public, government agencies, unions and businesses with accurate information about the various radiation-related aspects of VDTs.

2.0 RADIATION

As soon as they see or hear the word "radiation", many people think of atomic bombs, nuclear reactors, radioactive wastes, cancers and birth defects. Radiation is actually a more general term that describes the transfer of energy from one place to another without any obvious connecting link like a pipe or wire in between. Light is a form of radiation. Information displayed on a VDT screen reaches the eye by means of visible electromagnetic radiation (light). The eye focuses this visible radiation on the retina and the brain interprets the image of the display produced there. An extremely bright VDT display would be difficult to look at directly. An incandescent light, for example, is too bright to look at from a short distance. It also emits infrared radiation, the effects of which may be noticed by a warming of the skin.

Since the term radiation refers to the transfer of energy in general, it covers an extremely broad range of effects that includes the whole so-called electromagnetic spectrum, which is commonly broken down into seven sections: X-ray, Ultraviolet (UV), Visible, Infrared (IR), Microwave, Radiofrequency (RF) and Low Frequency (LF). These are shown in Figure 1. Static electric and magnetic fields, although not associated with radiated energy, also may be found in the vicinity of electrical and electronic equipment. Sound, including Infrasound and Ultrasound, constitutes yet another form of radiation, which transmits energy or information by means of mechanical vibrations in the materials through which it travels.

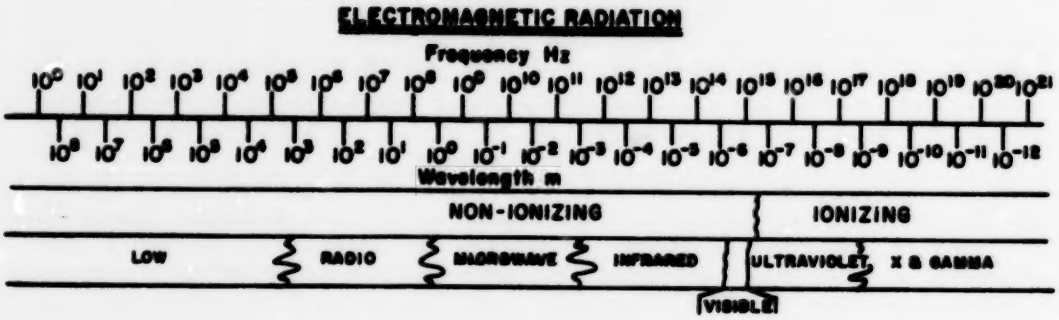

Fig. 1

3.0 HOW VDTS WORK

The key element in any VDT is a display device, usually a television (TV) picture tube, which is a rather large glass vacuum tube with a phosphor coating on the inside surface of its thick and fairly flat front face (Figure 2). An electron beam projected from the back of the tube hits the phosphor and causes it to glow. At the point where the electron beam strikes the phosphor, X-ray, UV, visible and IR radiations are generated. In addition, partly because of the constant flow of electric current (the electron beam) to the front face of the picture tube, a static charge can build up there.

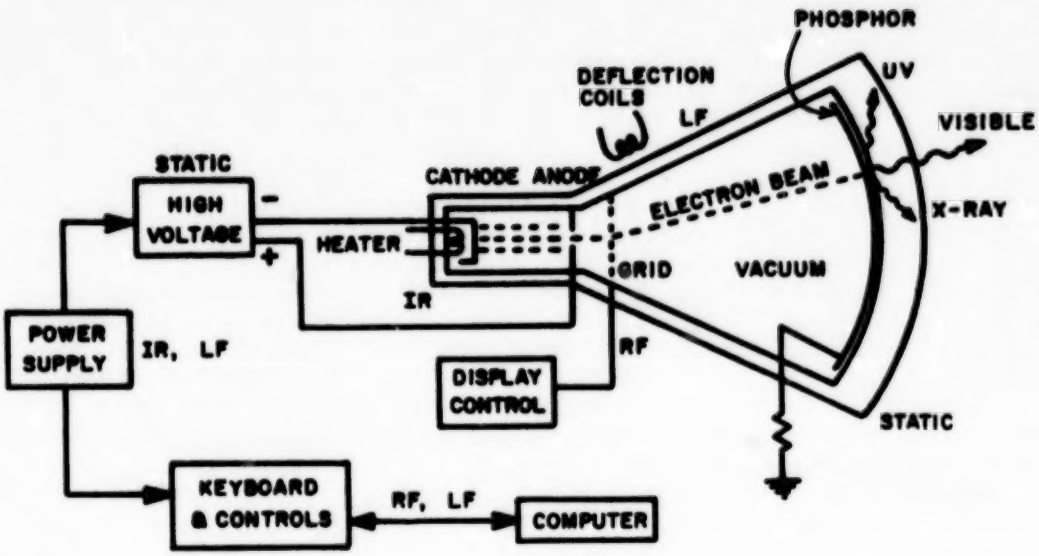

Fig. 2

The electron beam is moved around and turned off and on to light up different spots on the phosphor-coated screen and thus generates the display. The beam steering is usually done by magnetic fields produced by coils of wire (deflection coils) mounted near the back of the tube. These coils and the circuit that drives them give rise to emissions in the LF region of the spectrum. Mechanical effects in these components and circuits can also produce acoustic emissions in the ultrasonic region. The beam is turned off and on by a grid electrode controlled by a computer with the VDT. It is often possible to observe emissions in the RF region from these circuits, which also produce emissions in the LF region as a result of keying operations, page and line scrolling and other control operations.

At the back end of the tube the electron beam is projected from an electron gun. The electrons are released from a heated cathode. They are then accelerated toward the anode by a high voltage (around 15 000 V). They pass through a hole in the anode and proceed through the control fields to the screen. The various components in the circuits of the power supply, high voltage supply, keyboard and control circuits all heat up to some degree and consequently emit IR radiation. Finally, there are detectable fields in the LF region that result from the display refresh circuits and the line frequency (60 Hz) power connection.

The rest of this document deals with each type of electromagnetic radiation in turn. The limits referred to below are based on regulations or, where regulatory action has not been taken, on standards and guidelines proposed by widely recognized and authoritative agencies such as the Bureau of Radiation and Medical Devices (formerly the Radiation Protection Bureau) of Health and Welfare Canada, the Center for Devices and Radiological Health (formerly the Bureau of Radiological Health), the National Institutes of Occupational Safety and Health (NIOSH), the U.S. Occupational Safety and Health Administration (OSHA), the British Health and Safety Executive, and committees such as the Canadian Federal-Provincial Subcommittee on Radiation Surveillance, the National Research Council of Canada's Associate Committee on Scientific Criteria for Environmental Quality (through its former Subcommittee on Physical Energy Phenomena), the Physical Agents Threshold Limit Values (TLV) Committee of the American Conference of Governmental Industrial Hygienists (ACGIH) and the Standards Committees of the American National Standards Institute (ANSI). All these agencies and committees are in broad general agreement on the limits they propose, although there are some differences in details. They arrive at their recommendations after reviewing the scientific literature in each area and assessing its significance to workers and the public at large.

Scientists who specialize in the evaluation of the effects of exposure to radiation are unanimous in the view that the levels of radiation generated by VDTs do not constitute a hazard to the health of an operator or to a developing fetus.

4.0 X RADIATION

X radiation is a form of electromagnetic radiation. It is at the extreme high frequency end of the electromagnetic spectrum. When it interacts with matter, it can separate electrons from atoms and leave along its path a trail of charged atoms that are called ions. Thus, X radiation is also called ionizing radiation. Other forms of electromagnetic radiation that do not leave a trail of ions when they pass through matter are called non-ionizing radiations.

The magnitude of an exposure to ionizing radiation may be expressed in terms of the ionization it produces in air. The quantity is called <u>exposure</u> and its modern unit is coulombs per kilogram ($C \cdot kg^{-1}$). The former unit was the roentgen (R), and 1 $C \cdot kg^{-1}$ = 3876 R. The biological dose received by a person from an exposure to ionizing radiation is known as the <u>dose equivalent</u>. The modern unit of this quantity is the sievert (Sv) and the former unit was the roentgen equivalent man (rem). 1 Sv = 100 rem. Very approximately, an exposure of 1 R from X or gamma radiation delivers a dose equivalent of 10 mSv, or 1 rem.

People are continually exposed to many sources of ionizing radiation. Some examples of these so-called background sources are the radioactive materials in the earth (and in building materials), naturally occurring radon gas and its radioactive decay products, cosmic radiation from the sky, radioactivity in foods and residual fallout from atmospheric weapons tests. People are even exposed to ionizing radiation from within their own bodies. The main source of this exposure is the natural radioactivity of the 140 g of potassium in their lean tissue mass. To a smaller extent people are also exposed to radiation from the radioactivity in the bodies of others in their close proximity. Less frequently, additional exposure results from X-ray examinations and from enhanced levels of cosmic radiation received during air travel at high altitudes. An average Canadian would receive a dose equivalent of about 2 mSv (200 mrem) each year from all of these sources. Residual fallout causes about 0.03 mSv (3 mrem), a single chest X-ray would add about 0.4 mSv (40 mrem), while an upper gastro-intestinal tract examination would add 6 mSv (600 mrem) or more to an individual's dose.

By way of comparison, the X-ray emissions from a VDT are so low that they are all but impossible to detect. It has been calculated that a person working 8 hours a day for 250 days of the year <u>might</u> receive as much as 0.05 mSv (5 mrem) each year to the part of the body closest to the VDT - a rather insignificant addition to the total annual exposure. Measurements made by the Radiation Protection Bureau of Health and Welfare Canada show that the actual yearly doses are less than one thousandth of this estimate. It becomes clear that this dose is insignificant when one considers what has been discovered about the effects of exposure to ionizing radiation.

A dose of about 5 Sv (500 000 mrem), delivered to the whole body in a short time (for instance, in an atomic bomb explosion), will result, within a couple of weeks, in the death of about half of the people so exposed. The same dose spread out evenly over a whole year would not likely produce any noticeable early effects. However, it is known that in the next few years there would be an obvious increase in the incidence of leukemia, cancer and birth defects among the exposed people.

By contrast, if the dose of 5 Sv (500 000 mrem) is reduced by a factor of 2500 to 2 mSv (200 mrem), and spread out over a whole year, it becomes equivalent to background radiation. The effect of thus doubling the natural background exposure cannot be distinguished from the other detriments to human well-being that are in our environment. The contribution from VDTs, if any at all, would be <u>at least</u> a factor of 40 or 50 less.

Whenever electrons pass through a vacuum in the presence of a high voltage and strike a target material, X radiation is produced. The penetrating ability of the X radiation depends on how high the voltage actually is - the lower the voltage, the lower the penetrating ability. Medical diagnostic X-ray equipment is usually operated between about 70 000 and 100 000 V. Color TV sets and VDTs with full color displays may operate at as high as 25 000 or 30 000 V, but single color VDTs ("white", green, orange, etc.) virtually all operate below 20 000 V. Even at 30 000 V the thick glass face of the CRT is a very good shield against the X radiation produced inside the tube.

Measurements made with portable equipment that has relatively low sensitivity, on thousands of VDTs in a variety of office settings, have shown that emission levels do not exceed one-tenth of the limit permitted by Federal regulation. Laboratory measurements with much more sensitive equipment on fewer units failed to detect emissions in excess of natural background levels. Indeed, there are data available indicating that emissions are less than one-thousandth of background.

Thus, even though X radiation is generated at the inside surface of the glass face of the display tube, it is virtually all absorbed by the glass face of the tube because the radiation is not very penetrating and the glass is quite thick. Furthermore, the very low level of X radiation that might be emitted from the surface of any VDT is further attenuated by superficial body tissues before it can reach a fetus or the ovaries. In contrast, X radiation for medical and dental diagnosis is generated by machines that use much higher voltages than those present in a VDT since the radiation must be more penetrating to pass through the body and produce an "X-ray picture" for the medical or dental examination.

5.0 ULTRAVIOLET (UV) RADIATION

Ultraviolet radiation lies between X radiation and visible radiation (light) in the electromagnetic spectrum. It forms a bridge between the ionizing and non-ionizing regions of the spectrum. It has wavelengths that are too short to be detected by our eyes and therefore it is not visible. It is present in sunlight and it can cause sunburns (erythema), eye irritation (photokeratitis and conjunctivitis) and photosensitization. It has been associated with skin cancer and premature aging of the skin.

Some radiation in the UV region is emitted by some phosphors (the light-emitting material coated on the inside surface of the face of the display tube). In addition, the electrons responsible for producing X radiation also produce some UV radiation directly by similar processes.

However, although some UV radiation may be present within the CRT, it is not emitted in any significant amounts because the thick glass face of the display tube is an excellent absorber of UV radiation, especially of the shorter and more damaging wavelengths of the UV spectrum. Furthermore, laboratory measurements have shown that any UV emissions are several hundred times below the limit recommended for exposures of up to 8 hours per day.

6.0 VISIBLE RADIATION

Visible radiation is light. It is non-ionizing electromagnetic radiation in the very narrow range of frequencies or wavelengths that can be detected by our eyes. We are often exposed to the sun, a source of very intense visible radiation. The sun also emits large amounts of UV and IR radiation, measurable amounts of microwave and RF radiation, and even detectable (by satellites) amounts of X radiation.

Measurements have shown that the brightness level of the display of a VDT, which is usually adjustable for operator comfort, even at maximum is well below levels considered acceptable for extended viewing, and thus the display would not be considered hazardously bright. The light level from a VDT is generally much less than that from a domestic TV except when the VDT uses a reverse video display, and then they are comparable.

The color of the display - green, orange, etc. - is determined by the phosphor used in the VDT. A mixture is used for "white" displays and a combination (red, green and blue) is used for color displays. After-images and color perception shifts can occur as a result of looking at high contrast or single color visual fields. If such visual fields are also very bright, the feeling that the scene is burned right into the eyes is created. However, VDTs do not produce sufficient contrast or brightness for such effects to be strong enough to be damaging to the eyes, or otherwise hazardous to the operator.

7.0 INFRARED (IR) RADIATION

Infrared (IR) radiation is commonly referred to as radiant heat. It is what you feel when standing near an open fire or any hot object. IR radiation is adjacent to visible light in the electromagnetic spectrum at the red end of the visible region. It has wavelengths that are too long to be detected by our eyes and thus is not visible. It is another form of non-ionizing electromagnetic radiation.

At high intensities, IR radiation can cause skin burns. In industries where workers are exposed to very hot materials (molten metal or glass), it has been associated with the production of cataracts. However, the pain-sensing nerve endings in human skin provide a very effective warning indicator for IR exposures. Excessive exposure to strong sources of IR radiation, such as an open fire or a hot stove element, causes pain in exposed skin which forces one to move away.

As is common with any electrical or electronic equipment, VDTs heat up to some extent whenever they are turned on. Thus, they become sources of IR radiation. Furthermore, the emission characteristics of some phosphors are such that they emit some radiation in the IR region.

Laboratory measurements on VDTs have shown that IR emissions from them are about 500 times less than the recommended occupational exposure limit and about 5000 times lower than is required to feel "warmth". The warmth of the air blowing out of the VDT's cooling system should not be confused with IR radiation. Although that air has been partly heated by IR radiation within the VDT, most of its warmth results from contact with hot components in the VDT. The warmth one feels in that air stream is from contact with warm air rather than from exposure to IR or any other form of radiation.

8.0 MICROWAVE RADIATION

Microwave radiation is yet another type of non-ionizing electromagnetic radiation, but it has wavelengths even longer than those of IR radiation - roughly between 1 and 1000 mm. Microwave radiation is used for radar, communications and, for cooking purposes, in microwave ovens.

Microwaves are generated by very high frequency (billions of cycles per second) variations of electric current or voltage. VDTs and their associated computers currently do not normally operate on or generate such very high frequency variations. However, as computer technology advances, higher frequency signals in the microwave region of the spectrum will become more common, and microwave emissions will likely be detected near such advanced equipment.

The risk of cataracts is usually considered to be the most significant result of exposure to microwaves at intensities high enough to cause heating of the lens of the eye. In experiments with animals under exposure conditions where the heating of tissues has been shown to occur, effects such as resorption of fetuses, birth defects and blood and nervous system disorders have also been reported. However, such effects have not been found under exposure conditions corresponding to exposures at or below recommended limits.

Measurements of microwave frequencies near VDTs detect only background levels which are more than a million times less than the recommended limits in Canada.

9.0 RADIOFREQUENCY (RF) RADIATION

Radiofrequency (RF) radiation is another type of non-ionizing electromagnetic radiation which has wavelengths in the range of metres to kilometres. It is used to broadcast AM and FM radio and TV signals and also for CB, taxi, and police, fire and other emergency communications.

Experiments with animals at high exposure levels have indicated that RF radiation may cause a variety of effects associated with heating of the exposed tissue. However, where exposures do not exceed the recommended limits, there are no indications that such effects can occur in humans.

RF radiation is generated by high frequency (thousands or millions of cycles per second) variations of electric current or voltage. VDTs and their associated computers, like most other electrical and electronic equipment, routinely operate on and generate RF signals.

Inasmuch as virtually every piece of electrical or electronic equipment emits detectable amounts of RF radiation, VDTs are similar to radios, TVs, calculators, electric hand tools, shavers, hair dryers and automobile ignition systems. Laboratory measurements on VDTs show that the emission levels are more than a million times less than recommended limits. It has also been shown that, at any given location in a typical modern urban area, the total exposure to RF radiation from radio, TV and communications signals is greater than the exposure an operator might receive from operating a VDT.

10.0 LOW FREQUENCY (LF) RADIATION

Low Frequency (LF) emissions are electric and magnetic field variations that occur at a rate of a few through a few thousand cycles per second. The frequency used by utility companies to feed electrical energy from generating stations to homes and industry (60 Hz) is in this portion of the spectrum. LF emissions constitute yet another form of non-ionizing radiation that is emitted from VDTs.

LF signals are observed near the back or sides of VDTs, but they can also be observed near any other electrical or electronic equipment. Many domestic appliances such as electric blankets, stoves, toasters, refrigerators, etc. produce much stronger LF fields than those measured near VDTs.

An LF signal that can easily be detected near the back or sides of VDTs and TV receivers occurs at about 15 000 Hz and its harmonics. This emission comes from the high voltage circuit and

results from the signal used to scan the electron beam back and forth across the face of the display tube. These signals have been found to be much stronger near sets with non-metallic cabinets. Recently, to forestall growing speculation, controversy and criticism about these emissions, most manufacturers have been taking steps to reduce the levels emitted by their equipment. However, it remains a fact that the levels at the usual operator's position have been and continue to be far less than the recommended limits for this frequency region.

It has also been suggested that LF emissions, especially when modulated or pulsed at frequencies observed to occur in electro-encephalograms (brain waves), might somehow affect people exposed to them. All such reports available to date are quite speculative, and present indications from the scientific literature are that LF fields hundreds of times stronger than those observed near VDTs - pulsed, modulated or not - do not produce harmful effects.

11.0 STATIC FIELDS

Static electric fields occur when surfaces or objects collect an electric charge that is not carried away to ground. Their effect is usually experienced as a spark jumping from the fingers to a doorknob. This is especially common indoors under dry winter conditions.

Static fields can often be detected at the front face of a VDT or TV set. Sometimes the keyboard and enclosure (especially if plastic) will also carry a static charge.

The tiny sparks that occur in the presence of static fields can be annoying and, if they occur repeatedly, stressful. They can also cause the machine to malfunction and, possibly, cause the loss of a document or the failure of a component. For these reasons, many suppliers advocate the use of static control measures (humidifiers, static eliminators, conductive carpeting) to prevent such sparks. It has also been reported that operators become charged as a result of contact with VDTs. Consequently, it was suggested that dust particles and pollen can be attracted to them and cause allergic reactions. The possibility that this might occur can also be reduced by the use of static control measures.

However, apart from the annoyance caused by the tiny sparks, neither the sparks nor the fields have been shown to produce harmful effects in humans at the levels observed near VDTs. Even much higher fields have not been shown to be harmful. Papers reporting allergic skin reactions (rashes) secondary to exposure to static fields from VDTs noted that low humidity and carpets without antistatic qualities both had to be present for the observed effects to occur. They did not report on the incidence of rashes under similar conditions among workers who did not use VDTs. Thus, whether such effects are substantiated or not still remains to be determined.

Static magnetic fields are not to be expected in or around VDTs as such. The earth's magnetic field and residual fields from metallic furniture or building structures will be the main sources of static magnetic fields to which operators might be exposed. There are no indications that such fields produce harmful effects. Indeed, magnetic fields that are tens of thousands of times larger are used in magnetic resonance imaging procedures and are considered harmless.

12.0 ULTRASOUND

As was mentioned in Section 1.0 (Introduction), mechanical vibrations associated with the electron beam scanning control circuits can make some components in a VDT act like a very high frequency loudspeaker. In fact, the frequencies produced are so high that they are beyond the range of hearing of all but quite young people (up to early 20s) who may hear or complain about a high-pitched whistle or squeal from some machines. Such high frequency sound is sometimes called ultrasound. However, the term is more properly used to describe the very high frequency acoustic energy used in physiotherapy, in ultrasonic cleaners and in medical diagnostic procedures (for example, in examining the fetus during pregnancy).

Although the high frequency "ultrasonic" emissions may be annoying in the same way that the hiss from air conditioning systems or the hum from some lighting fixtures might be annoying, measurements indicate that the intensities are too low to produce any harm. For those people who can perceive the "ultrasound", the annoyance can be minimized by conventional sound deadening techniques.

13.0 OLD OR DEFECTIVE VDTS

It is often suggested that something could break down or fail in a VDT and cause radiation emissions to rise suddenly and without the operator's knowledge. In order to obtain information about this question, the U.S. Bureau of Radiological Health (BRH) undertook a study of 125 VDTs available on the open market. X-ray emissions were measured under extreme test conditions for which (a) line voltage is raised to 130 V from its normal value of 110 V, (b) both user and service controls are adjusted so as to maximize emissions, (c) the most important component or circuit failure is deliberately introduced, and (d) the screen still must generate a readable display. Under these extreme conditions the BRH reported that eight machines emitted between 0.5 and 2 $mR \cdot h^{-1}$ (i.e. in excess of the regulatory limit of 0.5 $mR \cdot h^{-1}$), two other machines emitted detectable levels under 0.5 $mR \cdot h^{-1}$, and the other 115 VDTs were reported as emitting 0.0 $mR \cdot h^{-1}$. The conclusion that can be drawn from this is that only in situations as bad as the extreme test conditions might 10% of VDTs produce detectable (though not necessarily hazardous) X-ray emissions.

It is extremely unlikely that a chain of coincidences as bad as the test conditions could ever occur during actual use of a VDT.

It is also extremely unlikely that emissions could rise to dangerous levels in the event of an ordinary component failure. The power supply and other circuits are designed to keep currents and voltages within certain limits so that, even in the event of a component failure, X-ray emissions will not exceed the regulatory limit. As with a TV set at home, when a component fails, the most likely result is a degradation in picture quality or in some other performance aspect of the system which thus terminates the exposure situation.

It is also often suggested that radiation emissions can increase as a VDT gets older. It is clear that, as VDTs get older, the effects of humidity, dust, temperature variations and vibration can result in component failures and unsatisfactory performance or display quality. In addition to component failures, the brightness of the phosphor usually decreases as the tube ages. However, neither this nor any other effects of aging would result in significantly increased emissions.

14.0 A FINAL WORD ON RADIATION

VDTs, like most other office machines or domestic appliances, do emit detectable amounts of various kinds of radiation. Recommended limits for all these radiations have been agreed upon by government and licensing agencies. Testing has covered a wide variety of makes and models and the whole gamut of applications from word processors to data entry and computer terminals in government and business to editorial, typesetting and classified ad departments in newspapers. Furthermore, testing has covered machines ranging from those that were a number of years old and wheeled around from one work station to another, to new machines that had been unpacked the very day that measurements were carried out. The tests confirm that operator exposures to the various radiations are all well below the recommended limits, and there is no reason to believe that VDTs are a hazard to the health of any operator or to a developing fetus. Thus, because there has never been a single substantiated report of a significant level of emission of any type of radiation in thousands of VDTs tested in offices throughout the world, precautions such as the routine monitoring of VDTs for radiation emissions, the transfer of pregnant operators to other jobs, the use of lead aprons and the installation of any extra shields or screens are quite unnecessary.

15.0 A BRIEF NOTE ON STATISTICAL "CLUSTERS"

Many operators of VDTs are alarmed by frequent reports of so-called "clusters" of miscarriages, birth defects and other adverse

pregnancy outcomes. It is not surprising that a pregnant operator of a VDT would become concerned for the safety of the child she is carrying after hearing about a situation such as was reported at the Toronto Star in 1980. In seven pregnancies among about 150 VDT operators in a one-year period, four resulted in children with birth defects.

However, two simple facts should serve to reassure anyone who is alarmed by such reports. First, a careful evaluation of radiation emissions and other physical and chemical factors in the environment did not reveal anything abnormal. Second, in a sample of pregnancies as small as seven, almost anything, even seven abnormal outcomes, can be expected to occur once in a while. In other words, even though such an occurrence will be very rare, it can be expected to actually happen when consideration is given to the large number of VDT operators in Canada. Furthermore, if the reported occurrence had been "real" rather than a statistical fluctuation or "cluster", there would have been an average of about four cases of birth defects in the same group of VDT operators (and any other group of 150 operators) in each subsequent year. This, of course, has not occurred. Thus, although the rarity of such an occurrence makes it worthy of note and results in its receiving a great deal of publicity, as well as intense study of the working environment by responsible experts, it is not an indication of any hazard to a pregnant VDT operator or her fetus.

Laboratory results for a typical VDT (Wolbarsht et al. 1979)

X-ray (>10 keV)	$0.003\ mR \cdot h^{-1}$ $(0.5)^{\alpha}$
Far UV (200 nm - 320 nm)	$1.25 \times 10^{-4}\ \mu W \cdot cm^{-2}$ $(0.1)^{\beta}$
Near UV (320 nm - 400 nm)	$1.8 \times 10^{-2}\ \mu W \cdot cm^{-2}$ $(1000)^{\beta}$
IR (700 nm - 4.1 μm)	$2 \times 10^{-3}\ mW \cdot cm^{-2}$ $(10)^{\beta}$
Microwave, E-field (10 MHz - 10 GHz)	$7.26 \times 10^{-9}\ mW \cdot cm^{-2}$ $(1, 5)^{\gamma}$
RF & LF, E-field (1 kHz - 10 MHz)	$1.3 \times 10^{-5}\ mW \cdot cm^{-2}$ $(10\ 000, 100, 1)^{\beta}$
RF & LF, H-field (1 kHz - 10 MHz)	$3.03 \times 10^{-5}\ mW \cdot cm^{-2}$ $(10\ 000, 100, 1)^{\beta}$

$^{\alpha}$ Federal Regulation.

$^{\beta}$ Provincial Recommendation.

$^{\gamma}$ Federal Safety Code.

( ) in right-hand column indicates guideline value. Two or more values indicate change of guideline within range given in parentheses at left.

Typical field survey results - 350 machines (Ontario Ministry of Labour)

X-ray (>6 keV)	<0.05 $mR \cdot h^{-1}$ $(0.5)^{\alpha}$
Microwave, E-field (300 MHz - 20 GHz)	<0.05 $mW \cdot cm^{-2}$ $(1, 5)^{\gamma}$
RF & Microwave, E-field (10 MHz - 2.45 GHz)	<0.5 $mW \cdot cm^{-2}$ $(1, 5)^{\gamma}$
RF, H-field (10 MHz - 300 MHz)	<0.05 $mW \cdot cm^{-2}$ $(1)^{\gamma}$
LF & RF, E-field (10 kHz - 200 MHz)	<1 $V \cdot m^{-1}$ $(600, 60)^{\beta}$
Static, E-field (<1 Hz)	<1 $kV \cdot m^{-1}$ $(10)^{\beta}$

α Federal Regulation.

β Provincial Recommendation.

γ Federal Safety Code.

( ) in right-hand column indicates guideline value. Two values indicate change of guideline within range given in parentheses at left.

< in right-hand column indicates emission too small to be detected. Number indicates sensitivity limit of instrumentation used.

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